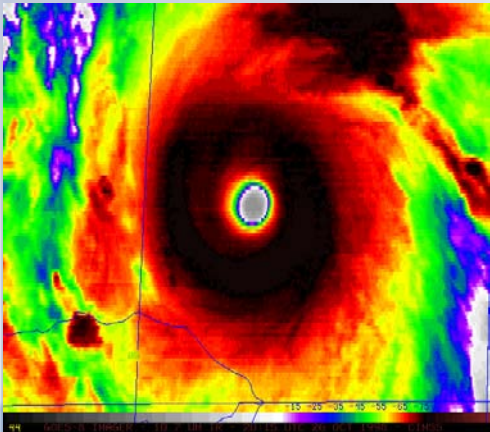


# Hurricane and Extreme Weather and Climate Connections

**Greg Holland**

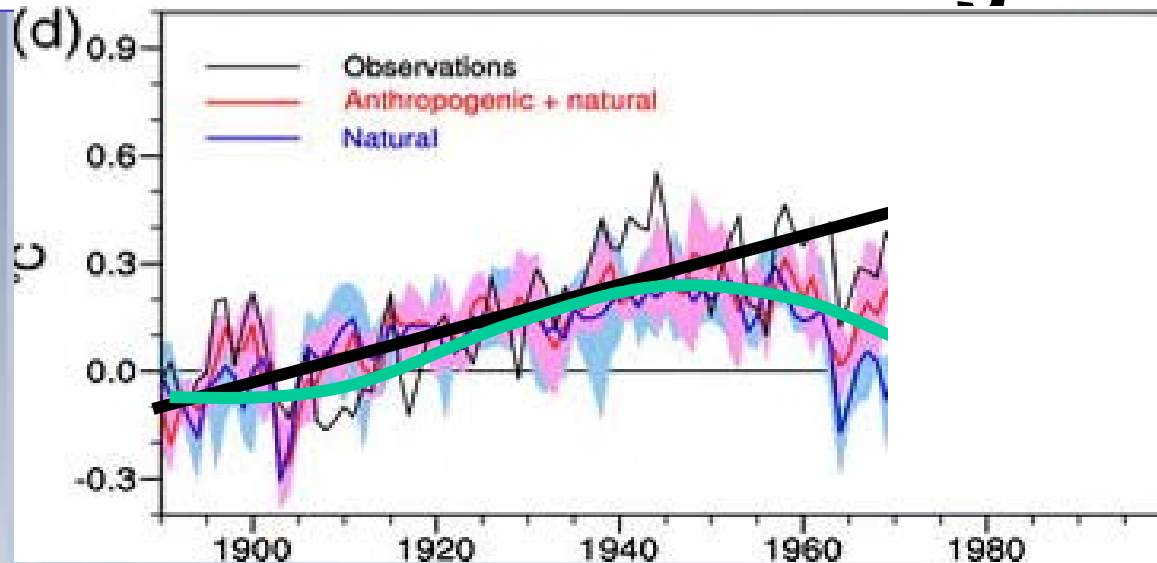
**National Center for Atmospheric Research**



Hurricanes, Extreme Weather and Climate 0809

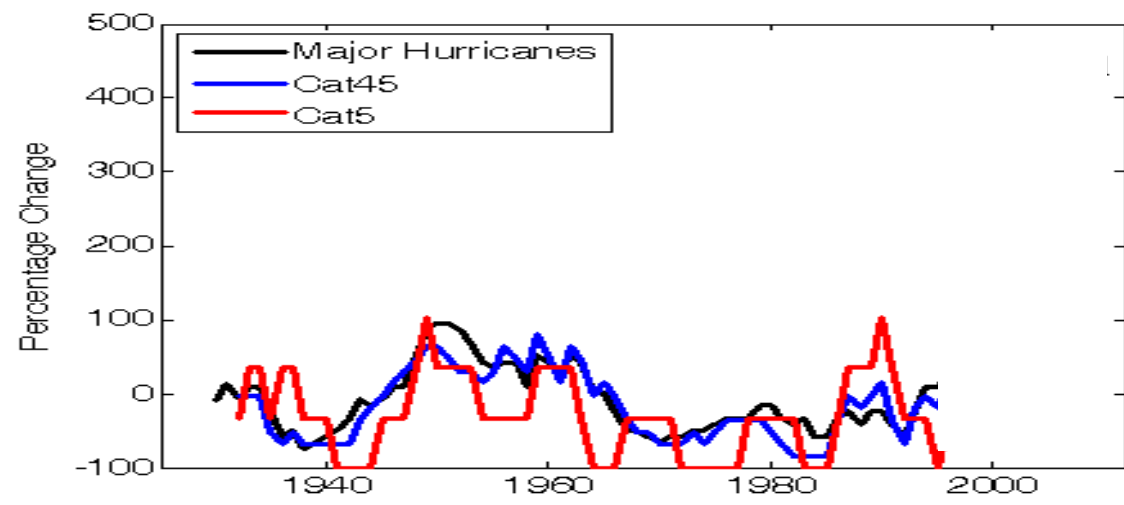
The Mesoscale & Microscale Meteorology Division

# Predicting Climate Variability and Change



“Variability” and “change” are hard, indeed often impossible, to logically separate.

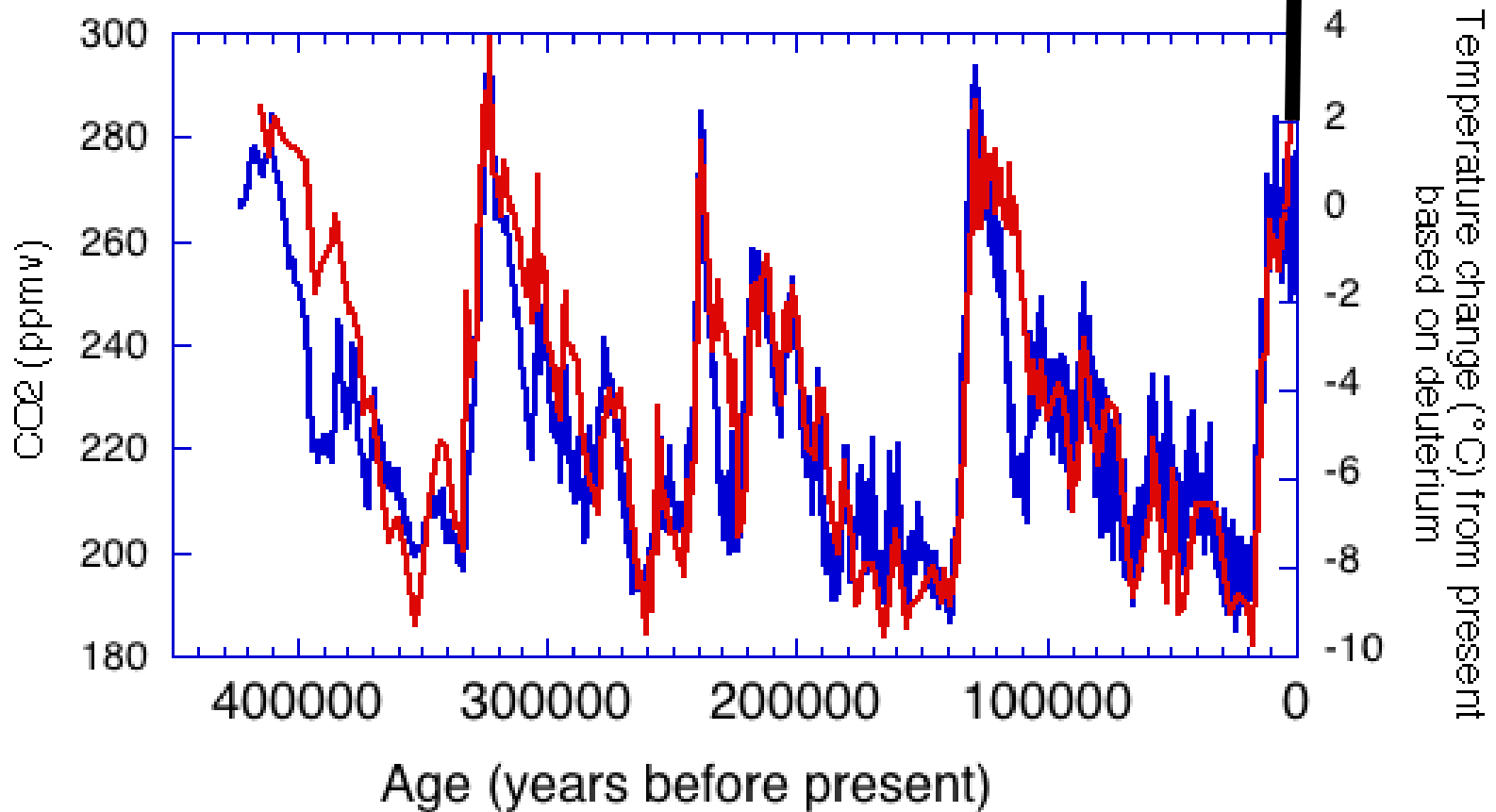
How do we understand and predict the consequences of change?



While history can give us some clues, climate models are the only useful tool.

# Impact of Anthropogenic Changes

[lwf.ncdc.noaa.gov/paleo/globalwarming/images/](http://lwf.ncdc.noaa.gov/paleo/globalwarming/images/)



# Extreme Weather Variations

- **IPCC:**

- *It is likely that heat waves have become more frequent over most land areas. {WGI 3.8, SPM}*
- *It is likely that the frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas. {WGI 3.8, 3.9, SPM}*
- *There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, and suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater.*



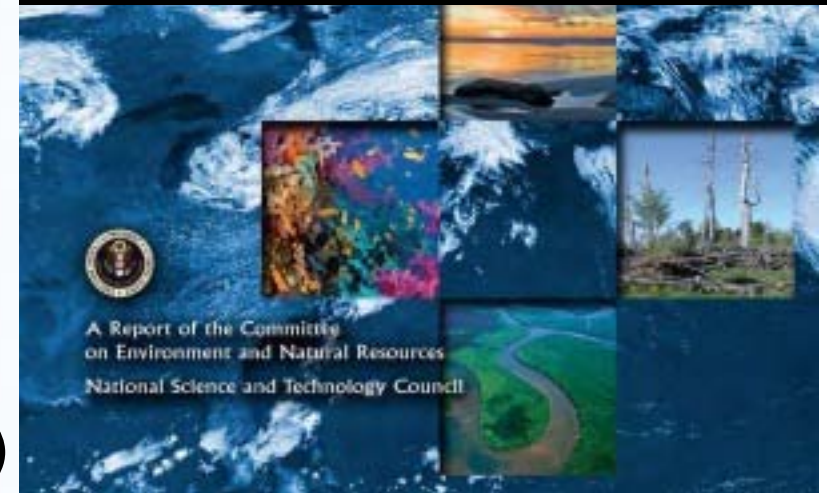
# Recent Peak Body Assessments

The US Climate Change Science Program (CCSP):  
Synthesis and  
Assessment Product  
Report 3.3

([www.climate-science.gov/Library/sap/sap3-3/final-report/](http://www.climate-science.gov/Library/sap/sap3-3/final-report/)) and,

The “Scientific Assessment  
of the Effects of Global  
Change on the United  
States by the National  
Science and Technology  
Council

([www.climate-science.gov/](http://www.climate-science.gov/))



Hurricanes, Extreme Weather and Climate 0809

The Mesoscale & Microscale Meteorology Division

# Hurricane-Climate Summary

- **Current Climate (CCSP)**
  - *Likely increase in hurricane frequency*
  - *Hurricane power has increased in recent decades*
  - *Landfall activity on US has not changed*
  - *Evidence suggests a human contribution*
- **Future Climate (CCSP)**
  - *Likely increase in rainfall and wind intensity*
  - *Frequency changes uncertain*
  - *Vulnerability will increase in the southeast and Gulf coasts*
  - *Communities once thought to have strong adaptive capacity remain vulnerable to hurricanes*
- **Seasonal Forecasts**
  - *Little demonstrable skill*



# Conjecture

*“Weather extremes respond to climate variability and change at much higher amplitude than the general weather-system population.”*

*“Extreme weather may thus provide a bellwether for climate change”*



# Precipitation Extremes



## Droughts

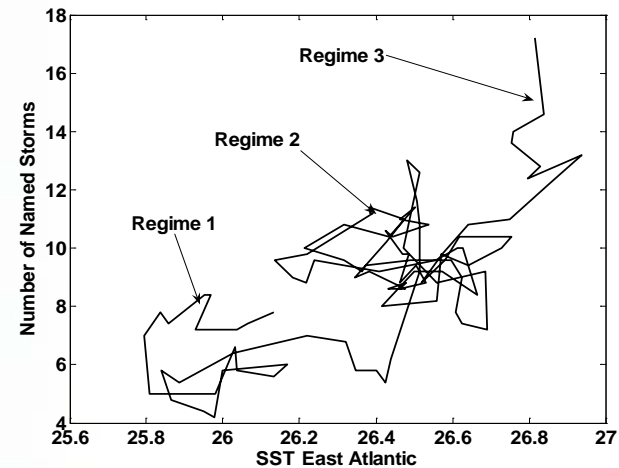
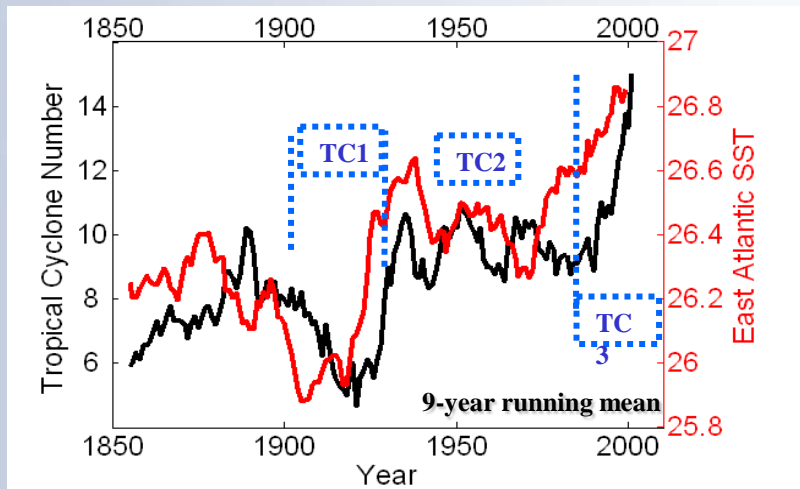
## And Flooding Rains



Hurricanes, Extreme Weather and Climate 0809

# Current Climate

- “it is *likely* that the annual numbers of tropical storms, hurricanes, and major hurricanes in the North Atlantic have increased over the past 100 years, a time in which Atlantic sea surface temperatures also increased.”



(Holland and Webster 2007)

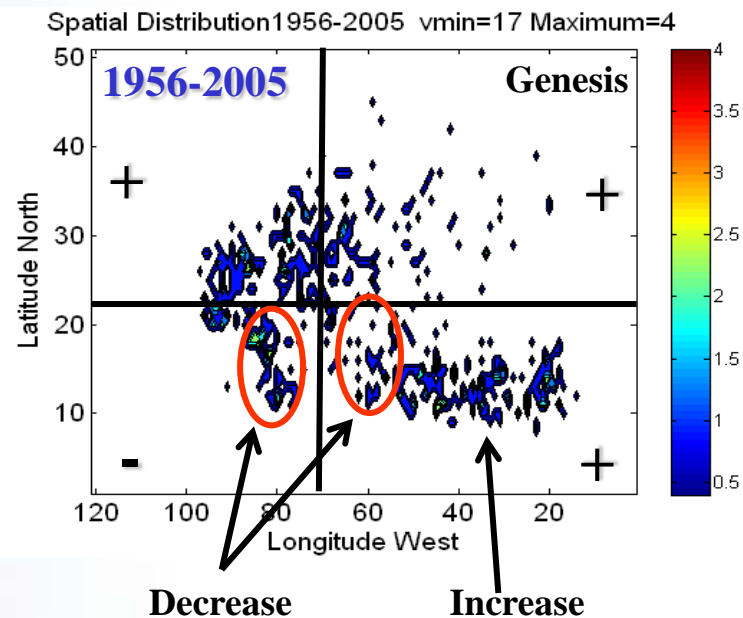
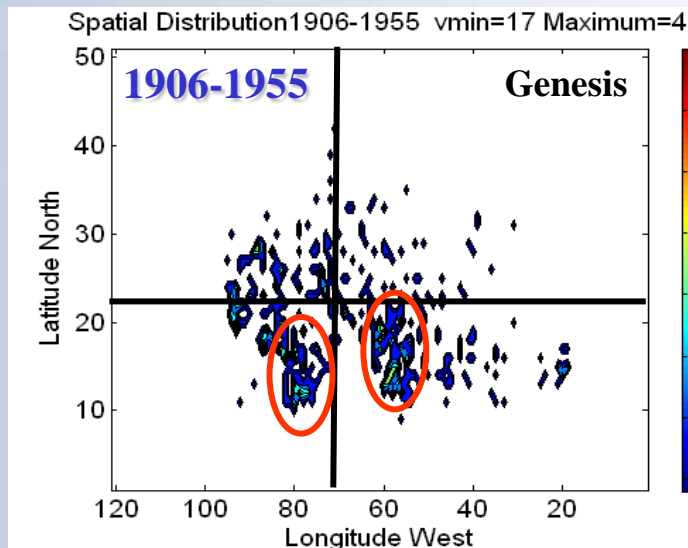


Hurricanes, Extreme Weather and Climate 0809

The Mesoscale & Microscale Meteorology Division

# Current Climate ctd.

- “The power and frequency of Atlantic hurricanes have increased substantially in recent decades, though North American mainland land-falling hurricanes do not appear to have increased over the past century.”



(Holland 2007)

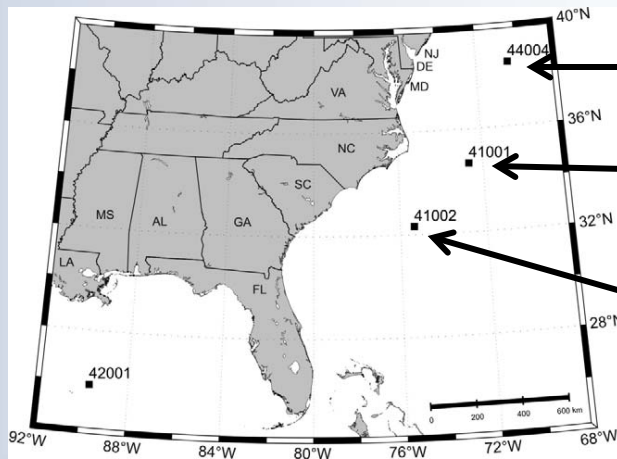


Hurricanes, Extreme Weather and Climate 0809

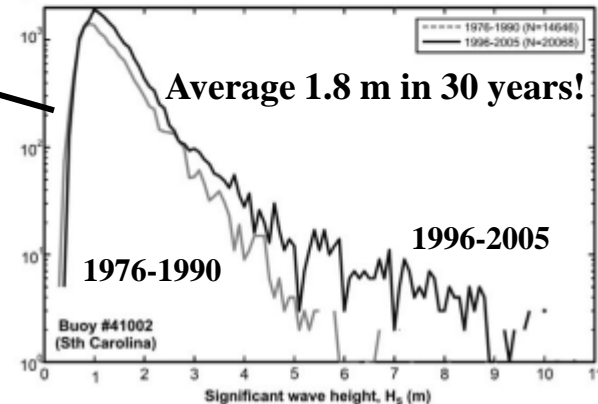
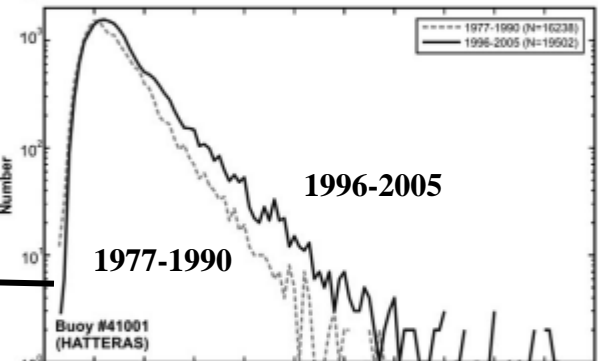
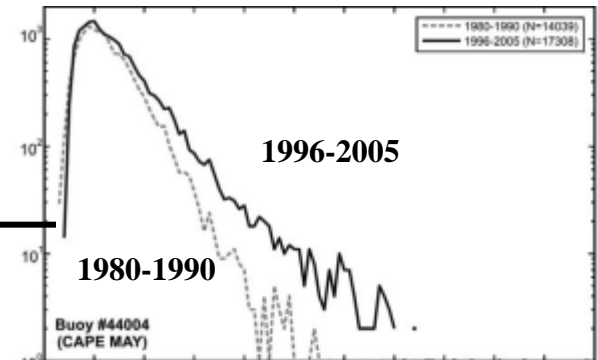
The Mesoscale & Microscale Meteorology Division

# Current Climate, ctd

- “Additionally, there is evidence for an increase in extreme wave height characteristics over the past couple of decades, associated with more frequent and more intense hurricanes.”



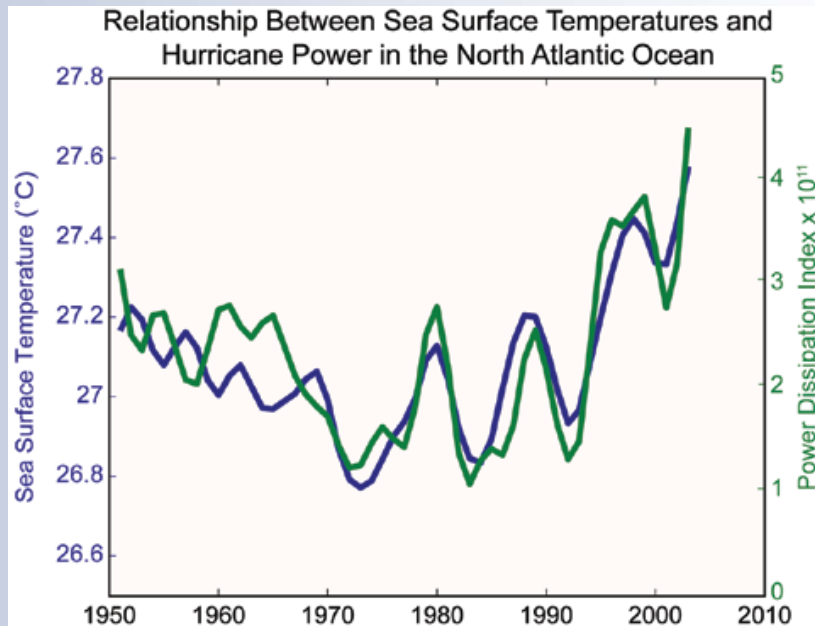
(Komar and Alan 2008)



Hurricanes, Extreme Weather and Climat

# Current Climate, ctd.

- “There is evidence suggesting a human contribution to recent changes in hurricane activity as well as in storms outside the tropics, though a confident assessment will require further study.”

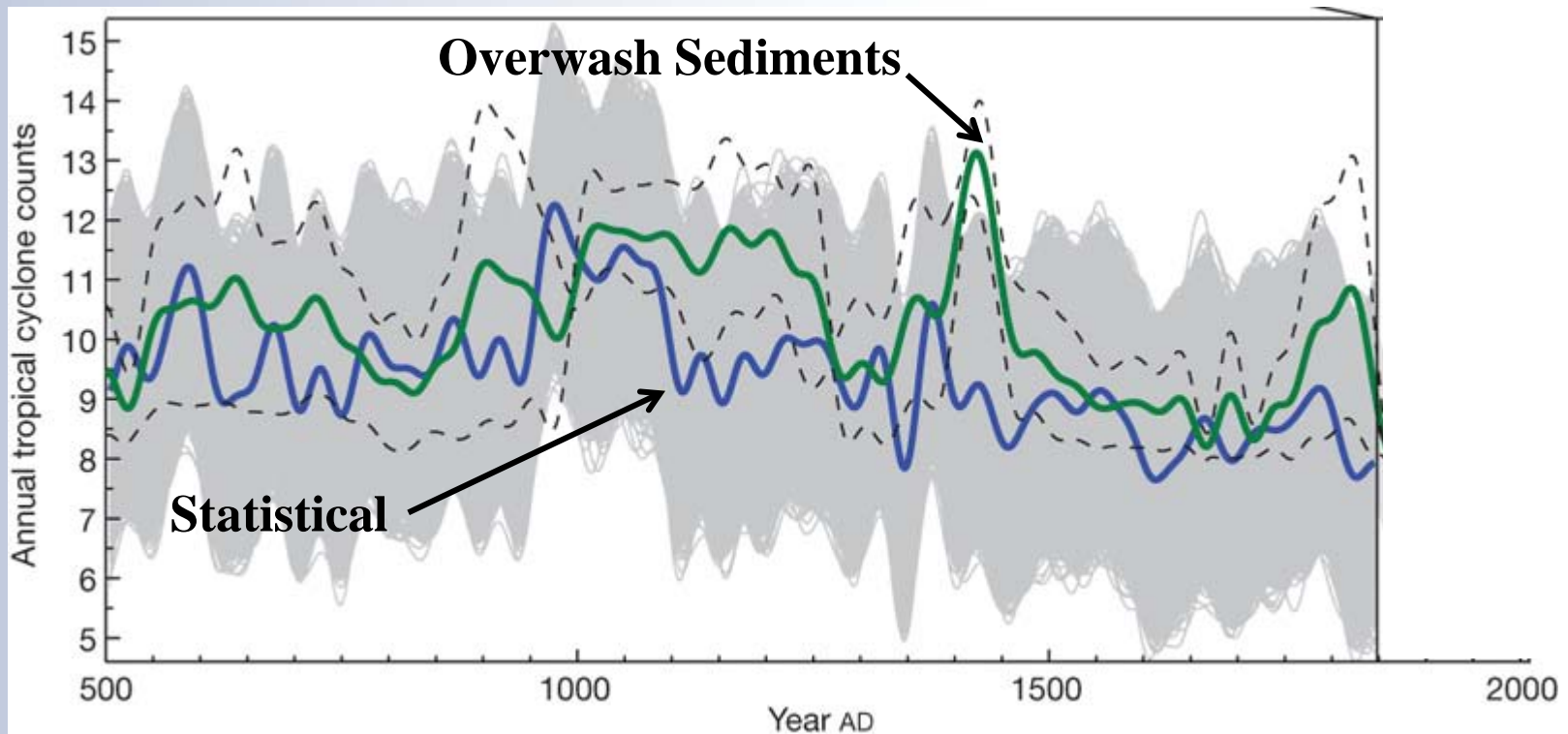


(Emanuel 2007)



# Historical Cyclone Frequency

Reconstruction of Atlantic tropical cyclone counts from AD 500.



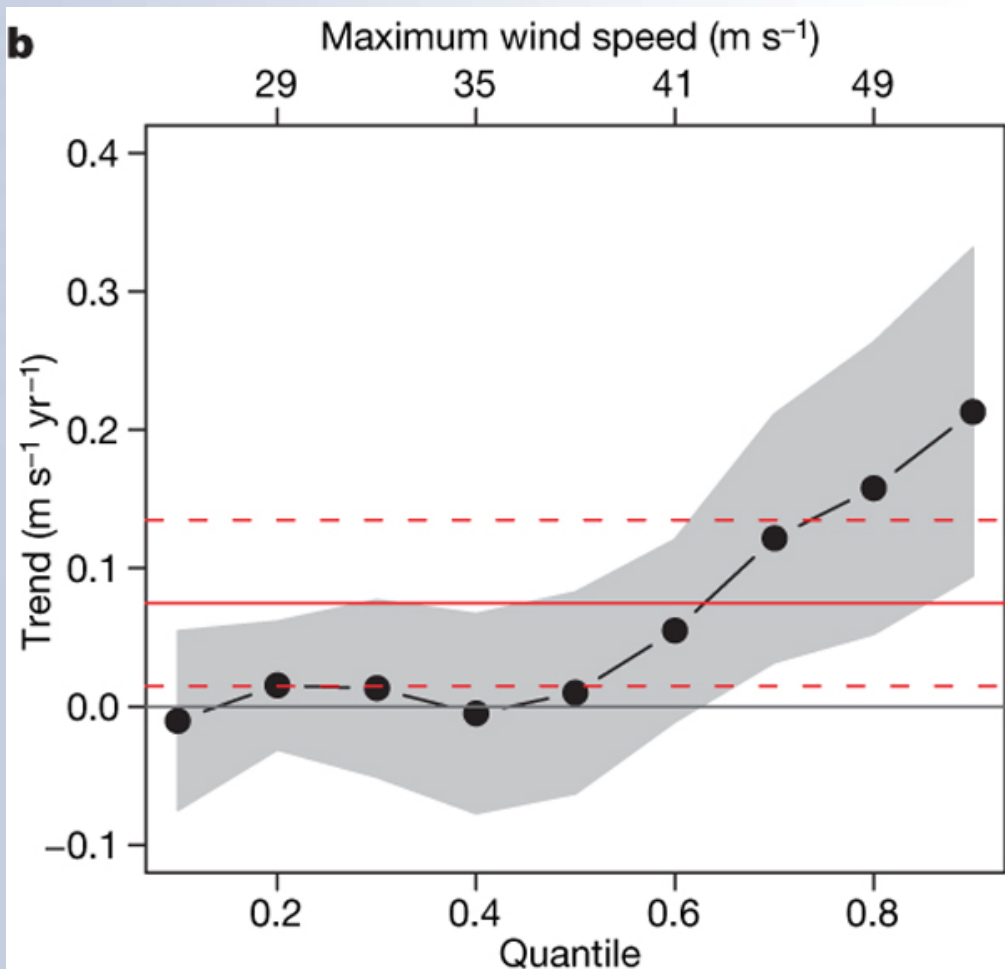
(Mann 2009)



Hurricanes, Extreme Weather and Climate 0809

The Mesoscale & Microscale Meteorology Division

# Extreme Tropical Cyclone Variations

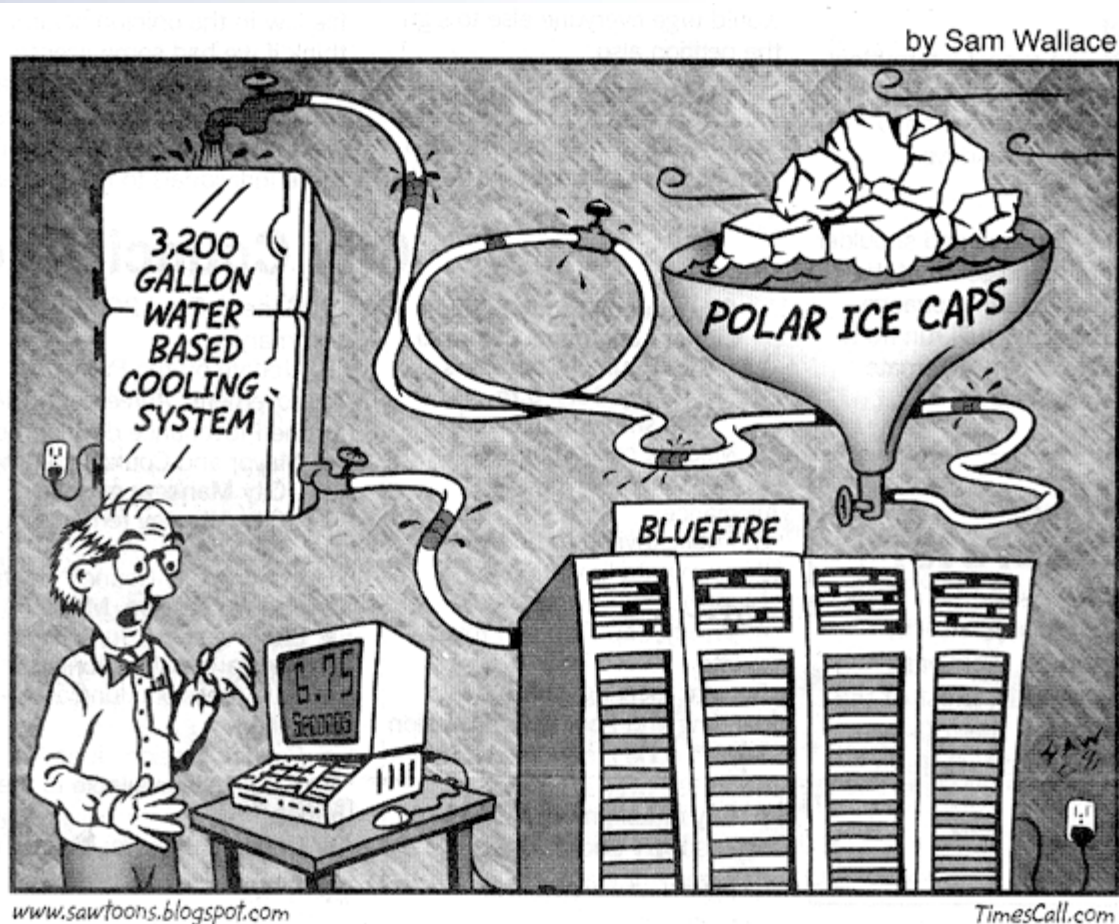


Developed from a  
homogeneous global  
satellite data set

Elsner et al (2008)



# Future Projections

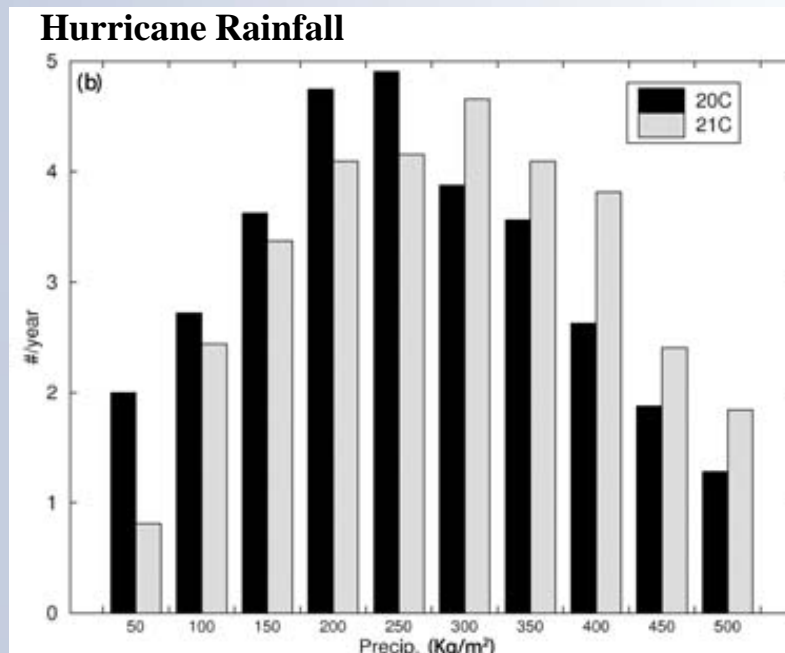


AT THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH IN BOULDER, SCIENTISTS DISCOVERED EXACTLY HOW LONG IT WOULD TAKE TO MELT THE POLAR ICE CAPS IF THEY USED THEM TO COOL THEIR NEW SUPER COMPUTER.

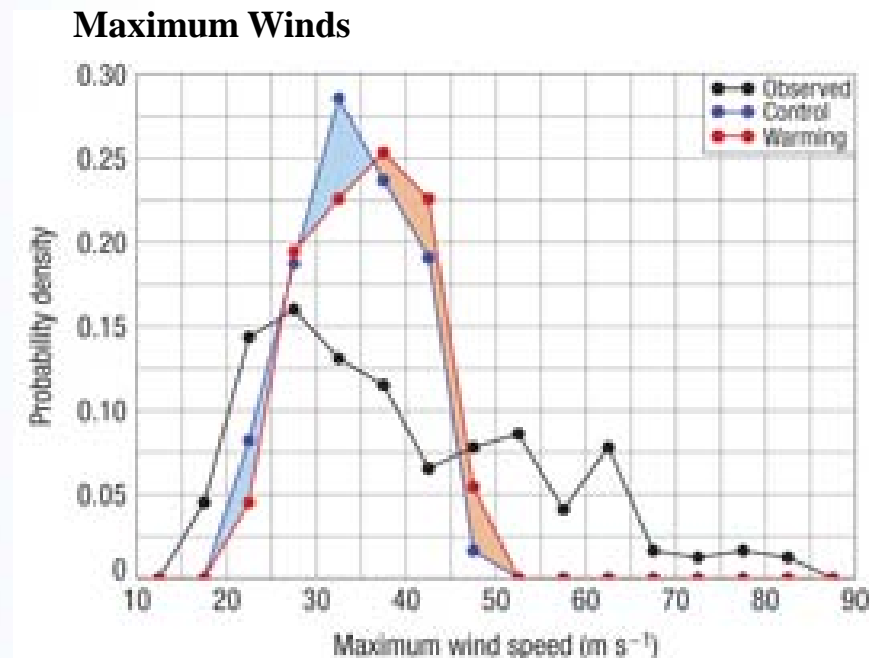


# Projected Rain and Winds

- “It is *likely* that hurricane rainfall and wind speeds will increase in response to human-caused warming”



(Bengtsson et al 2007)



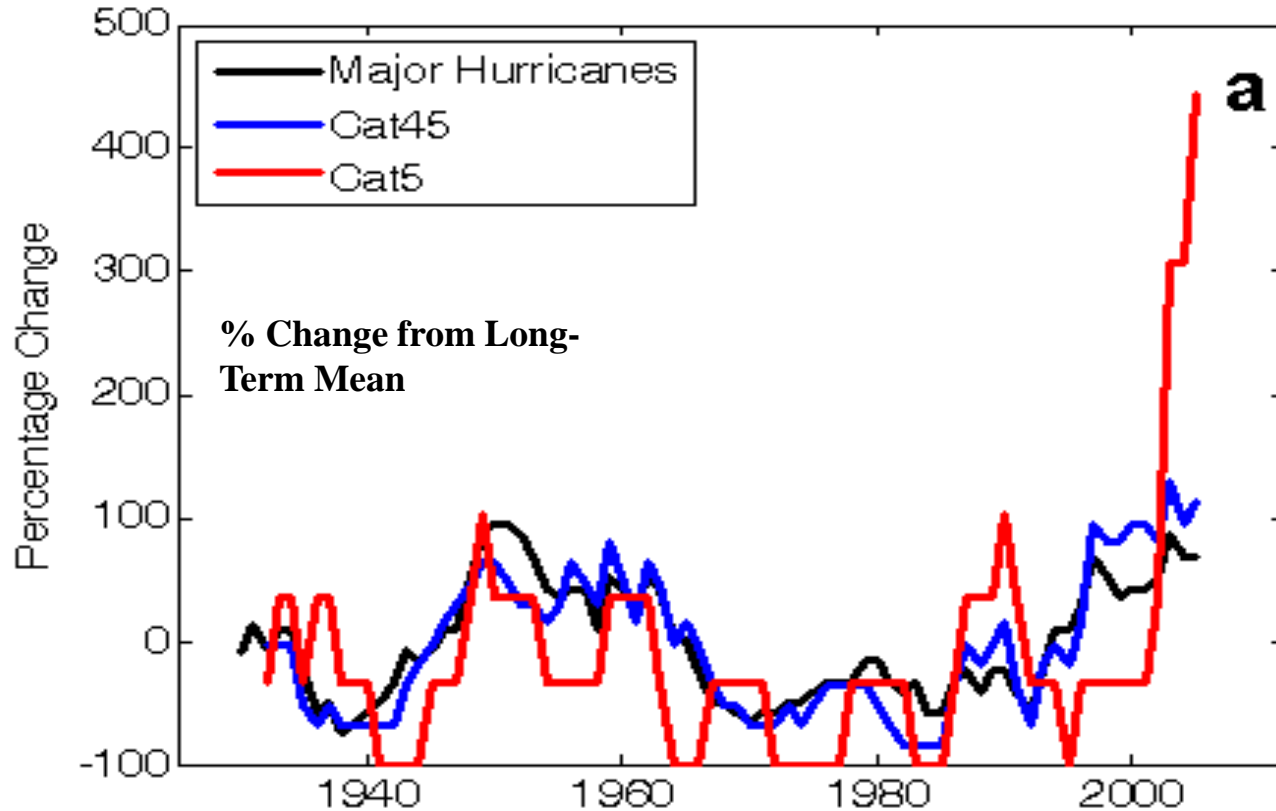
(Knutson et al 2008)



Hurricanes, Extreme Weather and Climate 0809

The Mesoscale & Microscale Meteorology Division

# Cat 5 Atlantic Hurricanes

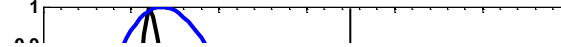
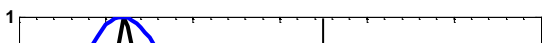


Amplitude extends well beyond any reasonable issues with data errors



Hurricanes, Extreme Weather and Climate 0809

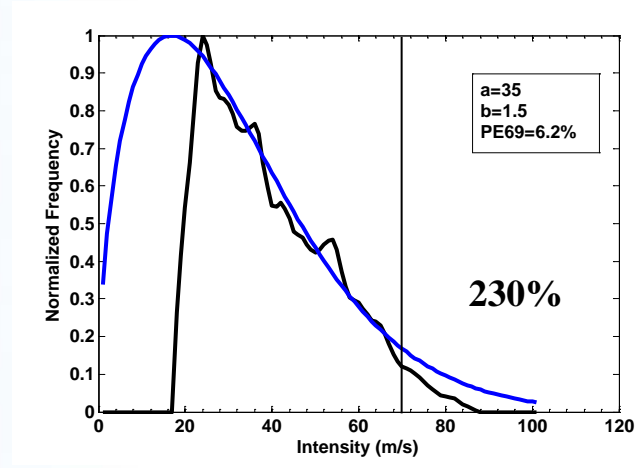
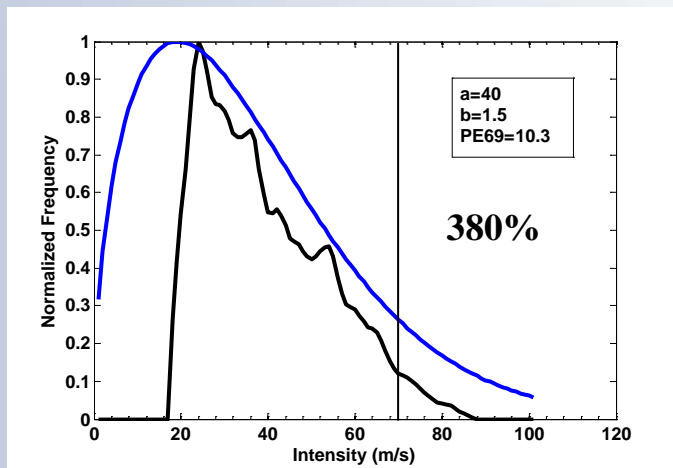
# Impact of Changes Based on Extreme Value Theory



Summary is that Cat 5 Hurricanes may increase by 100-200% for each °C warming of SST



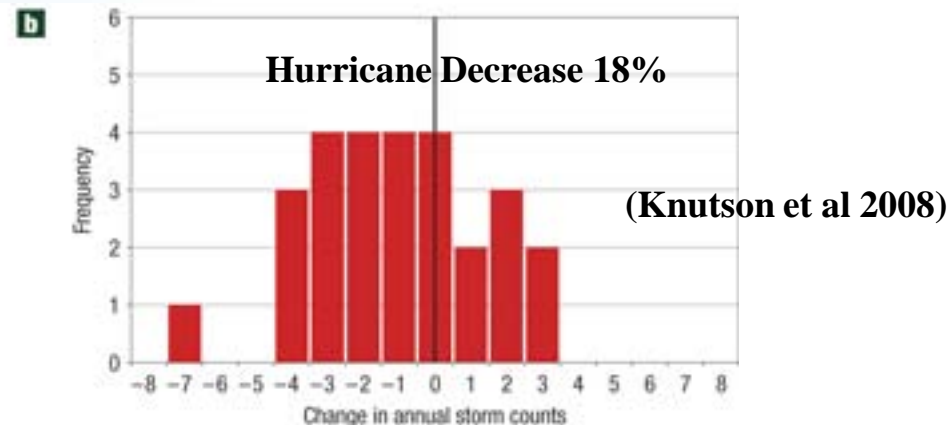
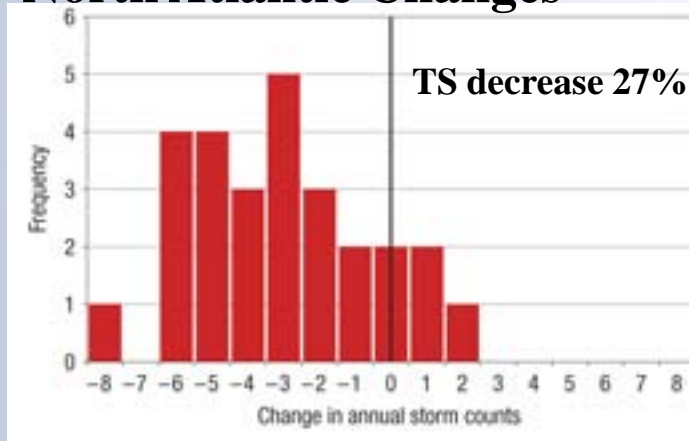
Intensity (m/s)



# Projected Frequency

- “There is less confidence in the projected changes in the number of tropical cyclones.”
  - *“The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period, highlighting the uncertainty associated with this issue.”*

## North Atlantic Changes



**Bengtsson et al (2007) 12.1 to 10.5 for North Atlantic**



# Future Hurricane Impacts

- Coastal population increases together with *likely increases in hurricane rainfall and wind speeds* and greater storm surge due to sea level rise will continue to increase coastal vulnerabilities in the Southeast and Gulf Coast.
- Urban centers that were once assumed to have a high adaptive capacity remain vulnerable to extreme events such as hurricanes.



# Extreme Weather-Climate Summary

- **Current Climate**

- *Extremes have increased*
- *Likely increase in hurricane frequency*
- *Hurricane power has increased in recent decades*
- *Cat 5 have more than doubled*
- *Landfall hurricane activity on US has not changed*
- *Evidence suggests a human contribution*

- **Future Climate**

- *Extremes are expected to increase*
- *Likely increase in rainfall and wind intensity*
- *Hurricane Frequency changes uncertain*
- *Communities once thought to have strong adaptive capacity remain vulnerable to hurricanes*
- *Intense Hurricanes may increase substantially.*

